Chapter

How Can Flaxseed be Utilized as Functional Food

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Abstract

Although vegetables and fruits are unquestionably important components of food, incorporating herbs and spices into one's diet has become a must to improve one's health in today's world. Due to rising popularity among health-conscious consumers, studies on functional foods such as herbs are a growing field in food science. Flaxseed (*Linum Usitatissimum* L.), which comes from the flax plant, an annual herb, is gaining interest as a functional food ingredient due to its high levels of alpha-linolenic acid (ALA), lignans, and fiber. Flaxseed consumption in the diet helps to prevent serious illnesses such as heart disease, cancer, diabetes, obesity, gastrointestinal, renal, and bone problems. Type II diabetes, in particular, is one of the great healthcare challenges of the twenty-first century, as it has engulfed children, adolescents, and young adults alike. While standard risk factors for type II diabetes are genetics, living style, and behavioral aspects, this article focuses on preventing or controlling the disease through dietary changes. To the best of our knowledge, review articles on the commercial use of flaxseed in the formulation of numerous food products with low glycemic index and their impact on diabetes are hardly available. The data from the previous 5 years is used to compile this report.

Keywords: bioactive compounds, diabetes, flaxseeds, functional foods, human nutrition

1. Introduction

Flaxseed, also known as linseed, is the seed of the flax plant, which is an annual herb that grows to about 2 feet tall and belongs to the Linaceae family. *Linumusitatissimum* is the Latin name for flaxseed, which means "most useful" and it is of two types: brown and yellow or golden. It's usually eaten in one of three ways: whole seed, ground powder, or oil. It was most probably first cultivated in Egypt, but it is now grown all over the world particularly in India, China, United States, Ethiopia, and Canada. Commercially, it was used in the manufacture of papers as well as clothes such as linen until the 1990s, though flaxseed oil and its by-products were utilized in livestock feeds [1]. Flaxseed has been consumed by humans since the dawn of time. However, it has sparked renewed attention in the areas of dietary intake and disease investigation over the last 30 years, owing to the significant health benefits associated with some of its bioactive components [2]. It contains about 40–50% oil, which is mostly made up of beneficial polyunsaturated fatty acids. It is high in omega-3 fatty acids, soluble and insoluble fibers, phytoestrogenic lignans, proteins, and antioxidants, among other nutrients. In the diet of vegetarians, it is a potential source of alpha-linolenic acid [3]. Flaxseeds contain

fats (41%), and dietary fibers (28%) as well as proteins (20%), water (8%), and ash content (3%). Flaxseed has a lipid content of 37 to 45 g/100 g and carbohydrate content of 25 to 30 g/100 g. Glutamine, Arginine, Valine, Leucine, Tyrosine, and Phenylalanine, Insoluble fiber constituents such as Cellulose, Hemicellulose, and Lignin are abundant in flaxseed, its meals, and isolated protein, while soluble fiber is made up of mucilage gums [4]. Flaxseed mucilage, which is mainly comprised of water-soluble polysaccharides, has greater water holding capacity and physico-chemical characteristics comparable to guar gum [5]. Flaxseeds contain three kinds of phenolic compounds: Phenolic acids, Flavonoids, as well as Lignans. The main phenolic acids found in defatted flaxseed are Ferulic acid, Chlorogenic acid, and Gallic acid. Flavone C- and Flavone O-glycosides are the most common Flavonoids found in flaxseeds. Secoisolariciresinol diglycoside is the main lignan found in flaxseed. Alpha-linolenic acid accounts for 53% of all lipids, with linoleic acid accounting for 17%, oleic acid for 19%, stearic acid for 3%, and palmitic acid for 5%, As a result, the n-6 and n-3 fatty acid ratio is usually 0.3:1 in flaxseeds [6]. Additionally, it contains minerals and vitamins, especially Phosphorus (K), Magnesium (Mg), Calcium (Ca), Iron (Fe), Zinc (Zn), and low concentration of Sodium (Na), as well as Vitamin A, C, Thiamine, Riboflavin, Niacin, B6, and E [7]. **Figure 1** shows the detailed picture of the nutritional profile of flaxseeds. It contains anti-nutrient compounds like phytic acid, linatine, and cyanogenic glycosides in addition to beneficial phytochemicals. Furthermore, this plant's ability to absorb and accumulate cadmium from the soil, which forms chelates with thiol-containing plant proteins, is a serious issue. Fortunately, no harmful impacts, such as food poisoning, have been reported in the literature as a result of Flaxseed consumption [2, 3].

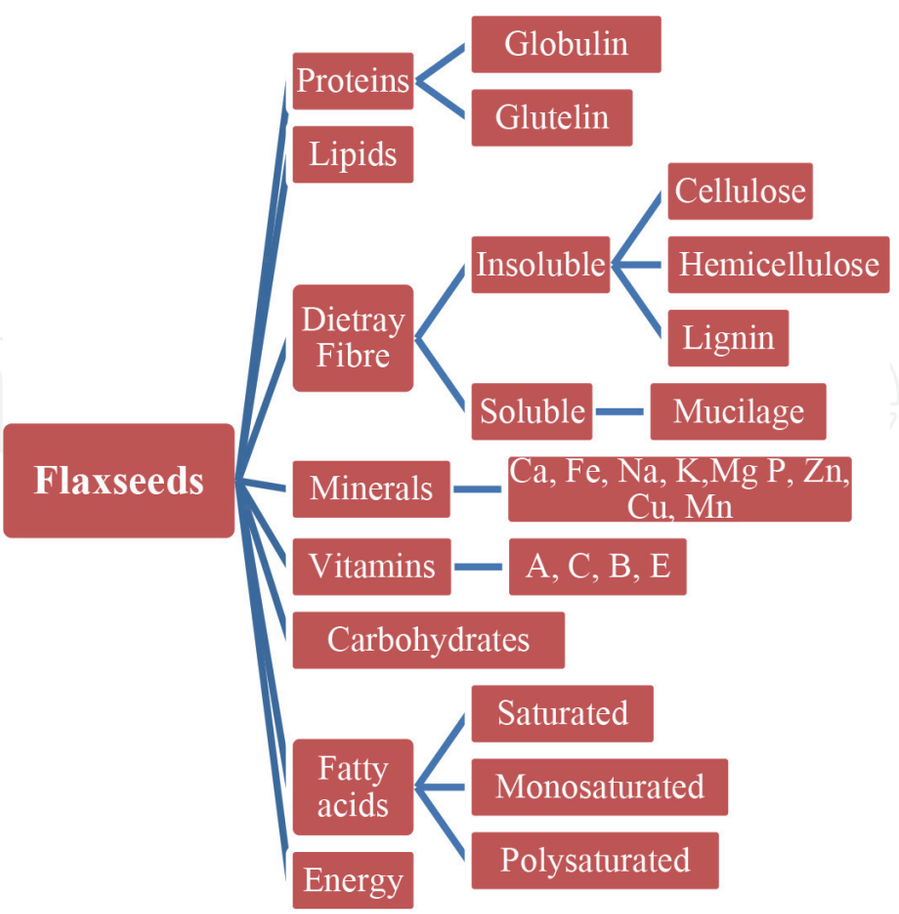

Figure 1.
Nutrient profile of flaxseeds.

Flax seeds contain numerous biologically active elements that help to prevent and treat a variety of physiological conditions and non-communicable diseases, including dyslipidemia, obesity, diabetes mellitus, a variety of cancers, kidney and renal failure, irritable bowels, immune function, and more. Their omega-3 fats, Lignans, and Fiber content are primarily responsible for their health benefits. Plant-based ALA fatty acids have been linked to a lower risk of stroke and have been shown to improve heart health. Lignans, which are rich in antioxidants and estrogen, may aid in the prevention of diabetes, breast and prostate cancer, as well as other cancers [8]. **Figure 2** demonstrates major health benefits provided by phytochemicals present in flaxseeds. Seed mucilage consumption via the oro-gastro-intestinal route has been linked to a variety of health benefits, including postprandial glycemic and insulinemic response modulation, hyperlipidemia prevention, satiety enhancement, and gut microbiota function regulation [9].

Diabetes Mellitus, also known as diabetes, is a metabolic condition characterized by raised blood sugar levels. A Hormone called insulin that transports sugar from the bloodstream into cells to be stored or used for energy, is responsible for diabetes. In diabetes, the body either does not produce enough insulin or does not use it effectively. Over the last 50 years, the number of diabetics and obese people has risen considerably in both developed and developing countries [10]. Both the International Diabetes Federation (IDF) and the World Health Organization (WHO) have made significant efforts to keep figures or global predictions of a sharp rise in the number of people with diabetes up to date. According to the IDF, 382 million people had diabetes in 2013, and by 2035, that number will have risen to nearly 600 million. **Figure 3** shows the International Diabetes Federation's global distribution of people with types 1 and 2 diabetes (ranked by country) [11]. Diabetes mellitus is linked to abnormalities in carbohydrate, protein, and lipid metabolism, which can lead to secondary complications. It can harm the heart, blood vessels, eyes, kidneys, and nerves over time. It raises the chances of having a heart attack or a stroke in adults by two to three times. Neuropathy (nerve damage) in the feet, when combined with reduced blood flow, increases the risk of foot ulcers, infection, and eventual limb amputation. Diabetic retinopathy is a common cause of blindness that develops as a result of long-term damage to the retina's small blood vessels. Diabetic nephropathy is one of the most common causes of kidney failure [12]. Basic lifestyle modifications have been shown to restrict the risk of type II diabetes or delay its onset. To aid in the prevention of type II diabetes and its

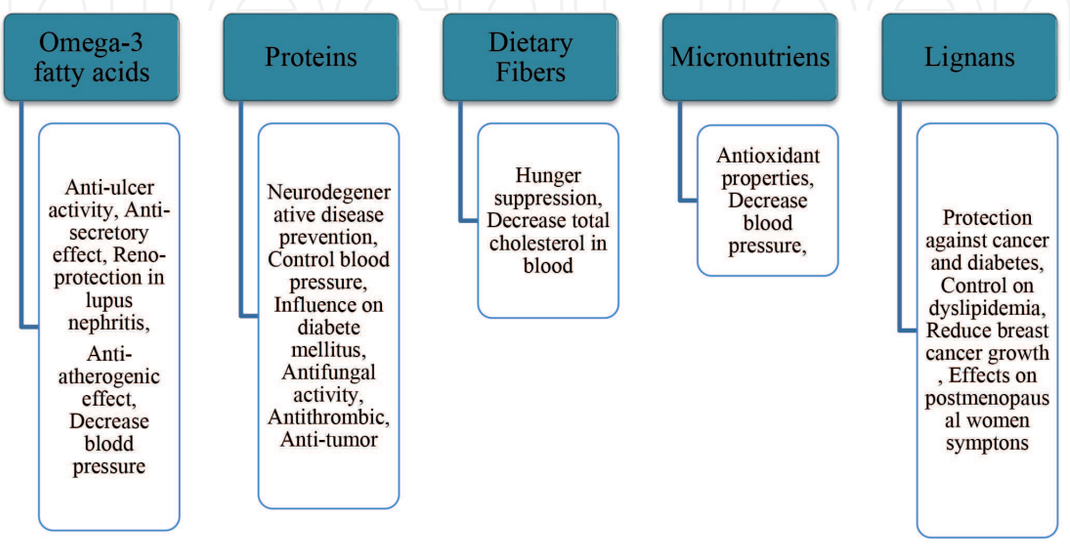

Figure 2.
Health benefits of flaxseeds.

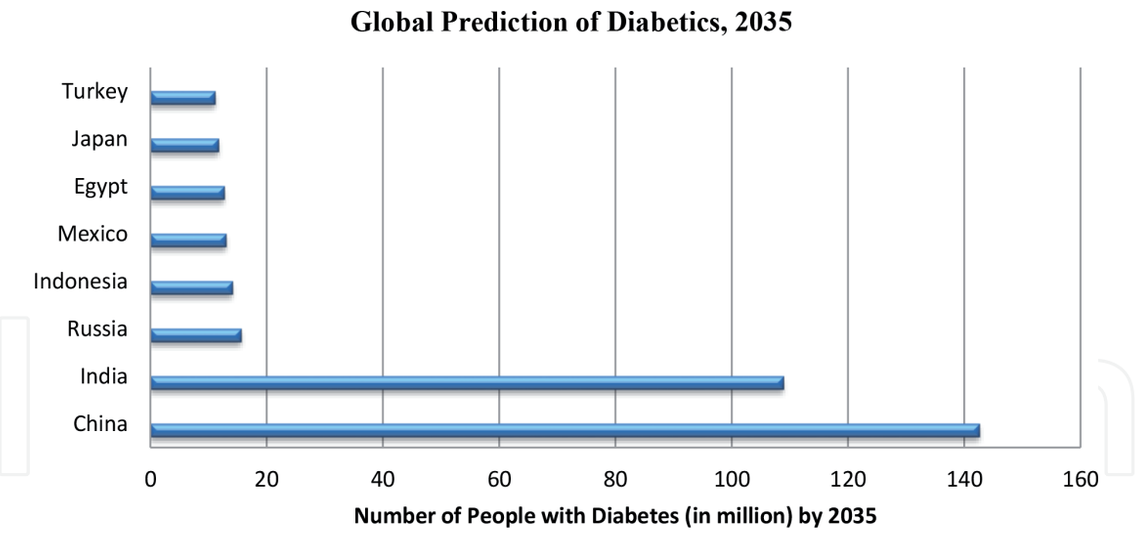

Figure 3.
Prediction of growth of diabetic patients, 2035.

complications, individuals should: attain and maintain healthy body weight; participate in physical activity; consume a nutritious sugar and saturated fat-free diet, and refrain from smoking. Because of the importance of lifestyle prevention, it's critical to look into the protective effects of healthy nutrients and foods. Numerous studies have shown that nutritional therapy plays an important role in preventing or delaying the advancement of these secondary complexities [13].

A diabetic diet focuses on a general dietary pattern including functional foods such as whole grains, nuts, fruits, leafy green vegetables, herbs, spices, legumes, and seeds that can help in managing blood glucose levels [14, 15]. Functional foods, which can boost health and lower the risk of developing many chronic diseases, have received a lot of attention over the last two decades. The concept "functional foods" was coined to describe foods that have been scientifically proven to have medical benefits [14]. Researchers have been focusing on the characteristics of bioactive substances found in functional foods in the management of multiple facets of diabetes mellitus in recent years; some of the therapeutic potentials of these bioactive substances and food sources have been studied in vitro and in vivo, and numerous analytical studies have even verified the benefits in people with diabetes. Hypoglycemic and Hypolipidemic properties have been discovered in a variety of functional foods [15]. Flaxseeds one of the functional food have been shown in studies to have hypoglycemic and hypolipemic properties, causing foods to have a lower glycemic index. It is high in dietary fibers, omega-3 fatty acids, and antioxidants, as well as being low in carbohydrates, making it an anti-diabetic food. Therefore, incorporating flaxseed into various food products causes positive changes in diabetics' biochemical profiles, thereby improving their metabolic profile [16]. This review summarizes data on flaxseed-infused foods and their importance in diabetes that has been published in the literature for the past five years.

2. Value-added food products prepared by incorporating flaxseeds

After centuries of use as natural medicine, Flaxseed has resurfaced in the functional foods arena as a potential future functional ingredient with a wide variety of clinical benefits. Flaxseed-supplemented food products are becoming increasingly trendy due to their high levels of unsaturated fatty acids, protein, soluble fiber, and phytonutrients. It can be used as roasted and ground seeds, and its oil can be used in

a variety of food formulations as vegetable oils, stable emulsions, and micro-encapsulated powder. **Tables 1** and **2** highlights the specifics of flaxseed-supplemented foods. Their impact on the glycemic index is also briefly discussed. The entire information on functional foods is divided into two categories: paper-based information and patent-based information.

2.1 Paper-based information

Published researches that include the food formulation containing flaxseeds have been included in this category.

Lifestyle choices, such as energy-dense foods and low levels of physical activity, significantly raise obesity rates and adipose tissue stores, leading to an increased risk of Type II Diabetes. Lifestyle changes, such as dietary changes, can help to reduce the risk of T2D. Flaxseed and its byproducts are becoming more popular as functional ingredients in low-glycemic-index foods as a result of their numerous health benefits. Until now, many efforts have been made to ensure the functionality of a wide range of cereal-based products, including bread, pasta, muffins, biscuits, and cakes. In this context, flaxseed hulls were investigated as a functional supplement for wheat bread enrichment and their relationship with the Glycemic Index. Furthermore, the antioxidant capacity, nutritional value, and consumer satisfaction all were investigated in 1–5% flaxseed hull (FH) supplemented wheat bread. Supplementation with 5% FH increased phenolic content by 93 percent, radical scavenging ability by 176 percent, and reducing power by 220 percent when compared to control. It was seen that fortification reduced in vitro starch digestibility slightly but had no effect on the expected glycemic index (eGI); however, it resulted in a reduction in relative protein digestibility of up to 8%. The addition of fortification reduced the volume of the loaf while enhancing the firmness of the crumb. The sensory evaluation results showed that the addition of FH particularly at higher doses had a slightly adverse impact on bread sensory properties but assure satisfactory customer acceptability [17]. According to these findings, flaxseed hulls might be a useful functional food in terms of nutrition, but they were not beneficial to diabetics.

Improving the content of soluble dietary fiber (SDF) in carbohydrate-rich foods is one strategy for lowering the risk of T2D. However, more research is needed into the glycemic response to specific soluble DFs, particularly the role of soluble DF-induced viscosity. Using a randomized, double-blind, crossover design, the acute postprandial glycemic response of puddings containing soluble DF derived from yellow mustard mucilage (YMM), fenugreek gum (FG), and flaxseed mucilage (FM), in 15 people (10 male and 5 female; age 55.1 ± 12.0 years; BMI 29.5 ± 3.4 kg/ m2) who were at extremely high risk of developing T2D was investigated. The nutritional composition of the puddings confirmed that the prepared puddings contained more energy and less fat. YMM incorporated pudding had the highest total dietary fiber content, while FG incorporated pudding had the lowest. Results revealed that all soluble DF puddings significantly reduced blood glucose and plasma insulin at maximum concentration and definite time points when compared to a control pudding, but not differed from one another [18]. This study showed that using viscosity-matched single DF in a pudding matrix can lower acute postprandial peak glucose and insulin levels, as well as the risk of T2D.

Another study looked into the use of oat (OB), flax (FB), and apple (AB) as dietary fiber (DF) fortifiers in wheat bread (WB). In this, wheat bread was compared to flax, oat, and apple bread. The fatty acid profiles were significantly altered when oat and flax fibers were added to bread. Oleic acid (33.83 percent of lipids) and linoleic acid were the most abundant in OB (24.31 percent of lipids). Only FB had a significant amount of Linolenic fatty acid with 18.32 percent. The

S. No.	Author and Year of Publication	Functional Food	Flaxseed Form	Amount of Supplementation	Reference
1.	Seczyk et al., 2017	Wheat Bread	Flaxseed Hulls	1–5%	[17]
2.	Kay et al., 2017	Pudding	Flaxseed Mucilage	2.28 wt%	[18]
3.	Kurek et al., 2018	Wheat Bread	Flax dietary Fiber	10.8%	[19]
4.	Zhu & Li, 2018	Steamed Bread	Flaxseed Flour	2.5–20%	[20]
5.	Zhu & Li, 2018	Noodles	Flaxseed Flour	25gm- 200gm	[21]
6.	Wandersleben et al., 2018	Bread	Flaxseed Flour	10.6%	[22]
7.	Soltanian & Janghorbani, 2018	Cookies	Flaxseed Flour	10g	[23]
8.	Soltanian & Janghorbani, 2018	Cookies	Flaxseed Flour	10g	[24]
9.	Yuksel, 2019	Noodles	Flaxseed Flour	10- 20g	[25]
10.	Hasaniani et al., 2019	Yogurt	Ground Flaxseed	30 g	[26]
11.	de Oliveira Giarola et al., 2019	Sherbet	Golden Flaxseed Flour	1–3%	[27]
12.	Tobias-Espinoza et al., 2019	Extruded products	Flaxseed Flour	6.6–9.3%	[28]
13.	Wirkijowska et al., 2019	Bread	Flaxseed flour & Marc	5–15%	[29]
14.	Geetha et al., 2020	Food Mix	Flaxseed Flour	—	[30]
15.	Sevostyanova et al., 2020	Bread	Flaxseed Flour	—	[31]
16.	Almehmadi et al., 2020	Muffins	Flaxseed Flour	30 g	[32]
17.	Campidelli et al., 2020	Ice-cream	Flaxseed meal Flour	1%	[33]
18.	Vieira et al., 2021	Liquid Thickener	Flaxseed Gum	0.6–1.5%	[34]

Table 1.
Information of Flaxseed incorporated functional foods, published since 2017.

bioaccessibility trials disclosed that the DF reduced saturated fatty acid intake. In the range of fatty acids, polyunsaturated fatty acids (PUFA) were the least bioaccessible (72 percent in OB to 87 percent in FB). In terms of glycemic load, the commercial bread had the highest value (80.5), which was markedly greater than the values for OB, FB, and AB. The addition of OB, FB, and AB resulted in low glycemic value. In addition, AB had the highest overall phenolic value (897.2 mg/kg), while FB had the least (541.2 mg/kg). In this study, AB had the only significant reduction in caloric values [19].

S. No.	Inventor/s	Title of Patent	Amount of incorporation of Flaxseeds	Patent Application Number	Reference
1.	Vadakkemuri Jolly Mathew	Optimized Nutrient Fatty Acid Composition	Flaxseed oil, 4.2–5.8 Liter	US2017/0360073A1, 2017	[35]
2.	Haijia Chen, Xiaohu Ge, Fei Wang, Yifei Wang, Jianqiang Cheng, Xiaoyan Wang	One kind is for diabetes B patient's diet and foodstuffs and preparation method thereof	Flaxseed oil, 4 parts by weight	CN107373642A, 2017	[36]
3.	Xiping Li, Xiao Han, YiminGao	A kind of compositions being applicable to diabetes patient and diet therapy soup thereof and preparation method	Flaxseeds powder, 5- 30 g	CN106266429A, 2017	[37]
4.	Jyoti Shirodkar	Food Products and Processes for Preparation Thereof	—	AU2017/100571A4, 2017	[38]
5.	Muhua Wang, Peiping Pan, Wei Song, Zhan Deng, Yuhong King, Binnan Su, YinghulCai, Xuxia Li, Xiaoxia Lu, Junfeng Gong	A kind of red yeast rice Flaxseed cake fermentate and its application	—	CN107136183A, 2017	[39]
6.	Chun xiao Li, Hongyu Luo	Diabetes full nutrition formula food and preparation method thereof made of a kind of seaweeds raw material	Flaxseed meal, 1% by weight	CN108522970A, 2018	[40]
7.	Tae Wan Kim	Method of producing a food for preventing and improving diabetes	Flaxseeds, 54.5–71.5% by weight	KR101850955B1, 2018	[41]
8.	Weiyi Wang	A kind of 3 sour milk powder of omega and its preparation process	Flaxseed oil powder, 15–25% by weight	CN104542974B, 2018	[42]
9.	Yingyan Chen	A kind of 3 solid beverage of omega	Flaxseed oil powder, 60–90% by weight	CN108685006A, 2018	[43]
10.	Vadakkemuri Jolly Mathew, Paul Thomson Kochery	Optimized Nutrient Food	Flaxseeds, 40-50 g	US2019/0335796A1, 2019	[44]

S. No.	Inventor/s	Title of Patent	Amount of incorporation of Flaxseeds	Patent Application Number	Reference
11.	Kewei Fang, Haijie Zheng, Yanbing Wu	Low-sugar mooncake high in fat and preparation method thereof	—	CN110384123A, 2019	[45]
12.	J. Murray Hockings	Method for treating and reversing Type 2 diabetes	Flaxseed oil, 500 mg	US10765318B2, 2020	[46]
13.	Jianzhang Lu, Shuang Li, Xuli Wu	Low-carbohydrate flaxseed nut wafer and preparation method thereof	Flaxseeds, 40–80 parts by weight	CN111466425A, 2020	[47]
14.	Scott Anderson, John Hall, Mark Yoho	Human dietary supplement and method for treating digestive system and immune-related disorders	—	WO2020081417A1, 2020	[48]
15.	Shiddalingesh Salimath	Enteral or oral nutritional composition	—	WO2020039277A1, 2020	[49]
16.	Jinho Pyo	Preparing method of noodle for improving diabetes, and the noodle obtained thereby	Flaxseeds, 5–30 parts by weight	KR20210012287A, 2021	[50]

Table 2.
Information about Flaxseed supplemented Functional Foods, patented since 2017.

Chinese steamed bread (CSB) is a fermented basic food popular in China and Asia. Because of the widespread usage and low cost of CSB, there are many chances to create 'nutritious' CSB with added natural products to combat the rising prevalence of chronic illnesses such as diabetes and cancer among the population. Development of CSB fortified with ground flaxseeds at a fortification level of up to 20% was investigated [20]. The resulting CSB was studied for its physicochemical, nutritional, and sensory properties. According to findings, Flaxseed addition reduced the specific volume and spread ratio of CSB while boosting unsaturated lipids, dietary fiber, phenolic content, and hardness in a dose-dependent manner. Flaxseed additions of up to 15% had a slight impact on the total acceptability of CSB. In terms of nutrition, adding flaxseed to CSB increased in vitro antioxidant activities while lowering in vitro starch digestibility and glycemic index from 117 to 97, and the glycemic load from 50 to 32.9 g.

In another study, fresh salted noodles with ground flaxseed flour that replaced wheat flour up to 200 g/kg were formulated. It was noticed that Flaxseed supplementation increased in vitro antioxidant activities while reducing the expected

glycemic index of cooked noodles in different dosages. The inclusion of flaxseed increased cooking loss whereas lowered the hardness and thickness of cooked noodles. According to kinetic analysis, adding 200 g/kg flax seed to noodles reduced the eGI from 60 to 52. Flaxseed replacement reduced the glycemic load of the noodles significantly, from 13.4 g in control noodles to 8.5 g in noodles with 200 g/kg flax seed addition in a dose-dependent manner. The noodles developed in this study were found to be beneficial to people suffering from chronic diseases such as diabetes and stroke [21].

Soluble fiber, protein, and resistant starch-rich foods aid digestion and may improve blood sugar response after meals. In this instance, three ingredients in bread production strike equilibrium between nutrition and palatability: lupine grit flour which consists of 60 percent protein, lupine hulls flour, and flaxseed expeller flour which is an excellent source of dietary fiber all were tested for their medical benefits. A customer acceptability test was also conducted on 259 volunteers using the bread deemed best by its balance of sensory and nutritional value. Compared to the control bread the final bread had 125 percent more fiber and 55 percent more protein. In all aspects surveyed, the bread was rated as acceptable by more than 90% of those polled. It was discovered that lupine can replace animal protein very well, and in addition, flaxseed supplemented bread had hypoglycemic properties [22].

In 53 constipated T2D patients, the effects of baked flaxseed cookies versus placebo cookies on constipation symptom scores, body mass, blood glucose, and lipid control were compared. Constipated T2D patients with BMI 20.5–48.9 kg/m2 were randomly assigned to either 10 g of flaxseed cookies two times a day or placebo cookies, for twelve weeks in a single-blind, randomized controlled trial. Participants in the control group were given sugarless orange-flavored maltodextrin cookies as a placebo. Constipation symptom rating, BMI, fasting blood sugar, glycosylated hemoglobin (HbA1c), and lipid level were measured at the start and end of four, eight, and twelve weeks. A stool diary was used to assess constipation. It was observed that the flaxseed group's constipation symptom scores (2.46), weight (3.8 kg), BMI (1.5 kg/m2), FPG (26.7 mg/dl), cholesterol (37.3 mg/dl), triglycerides (10.4 mg/dl), LDLC (21.0 mg/dl), HDLC (4.7 mg/dl), and cholesterol/HDLC ratio (1.4 mg/dl) all decreased significantly from reference point after the 12-week intervention. The differences in absolute change between the flaxseed and placebo groups in all of the studied profiles were statistically significant. This study found that eating 10 g of flaxseed baked into cookies every day for 12 weeks improved constipation symptoms, glycemic and lipid control, BMI, and body weight [23]. Following this study, the effects of baked flaxseed or psyllium versus placebo on constipation symptoms, weight, glycemia, and lipid levels in T2D patients were also compared. Psyllium is a soluble, viscous, gel-forming non-fermented fiber supplement that contains pentoses, hexoses, anduronic acids. It has previously been shown to reduce constipation signs, body fat, glycemic, and lipid profile. In constipated T2D patients, no medical study had done to compare the effects of flaxseed and psyllium on lowering constipation symptoms, mass, glycemic, and lipid status. As a result, 77 patients participated in this clinical trial. 77 constipated T2D patients were randomly assigned to three groups in a single-blinded, randomized controlled trial. For a total of 12 weeks, patients were given either 10 g flaxseed or psyllium supplemented cookies or placebo cookies twice a day. Constipation symptoms (P 1/4 0.002), stool consistency (P 0.001), weight (P 0.001), BMI (P 0.001), FPG (P 1/4 0.004), cholesterol (P 1/4 0.010), LDLC (P 1/4 0.031), and cholesterol/HDLC ratio (P 1/4 0.019) all improved significantly in the flaxseed and psyllium groups compared to the placebo group. It was observed that although both flaxseed and psyllium could help with constipation, weight loss, glycemic control, and lipid levels, flaxseed appears to be better than psyllium [24].

Raw flaxseed-enriched noodles were prepared and their physical properties such as Resistant Starch (RS), Total Starch, Total Dietary Fiber (TDF) content, estimated glycemic index (eGI) value, and nutrient composition of the resultant product was investigated. Flaxseed was added to the noodle blend in 3 different amounts (10, 15, and 20 g/100 g). According to findings, the RS content of the samples was found to be in the range of 0.61–2.14 g/100 g, with the sample containing 10% flaxseed having the highest RS. The noodle sample enriched with 20% flaxseed had a maximum TDF value of 8.28 percent, while the control had a value of 1.68 percent. The flaxseed addition did not affect the estimated eGI of the samples, but it showed very little impact on the mineral content of the noodle samples. Sodium, potassium, magnesium, and phosphorus were the most common mineral compounds found in the samples [25]. It could be concluded that a 10% flaxseed supplemented noodle would be a healthy and nutritious effective alternative to consume, but it would be less effective to diabetics.

An investigation was done to see how flaxseed enriched yogurt affected the elevated glucose and lipid levels, along with hypertension in T2D patients. On 57 patients with T2D, a randomized, open-label, controlled clinical trial was performed. For 2 months, participants were given either 200 g 2.5 percent fat yogurt with 30 g flaxseed or plain yogurt. At the start and end of the study, anthropometric and biochemical parameters were assessed. The findings revealed that Hemoglobin A1c levels in the treatment group were significantly lower than in the control group after 2 months of supplementation. At the end of the trial, there were substantial variations in triglyceride and total cholesterol ($p = 0.04$ and $p = 0.01$), systolic blood pressure, and diastolic blood pressure ($p = 0.02$ and $p = 0.002$, respectively) seen between flaxseed enriched yogurt and control groups. Fasting blood sugar levels were also reduced. Moreover, no differences in low- as well as high-density lipoprotein, body mass, or waist size were found between the two groups [26].

Sherbet is a frozen dessert just like ice cream, but it is made with more fruit pulp and has a more acidic flavor. In addition to glycemic load, two major parameters that should be considered for good quality ice cream, sherbet, or sorbet are sugar crystallization and ice recrystallization. The unwanted mechanism of ice recrystallization occurs during the processing and storage of ice creams and sherbets. In this context, analysis of the effects of different concentrations of golden flaxseed flour (GFF) on the glycemic index and ice recrystallization in uvaia (Eugenia pyriformis Cambess.) diet sherbets fortified with iron was studied. In the study, samples were moved from a freezer designed to perform 14 temperature fluctuation phases ranging from 20 °C/12 h to 10 °C/12 h from storage (25 °C) (each cycle, 48 h). Before the temperature cycles, the chemical structure, acidity, and physical parameters such as overrun, rheology of static and transient shear, firmness, thermal properties, and crystallite sizes were evaluated. An optimized descriptive profile was used to evaluate the sensory attributes. The findings revealed that the glycemic load decreased as GFF concentration increased, while the ash content and pH values increased significantly. GFF addition was found to be a viable option for the preparation of an iron-fortified uvaia diet sherbet with a reduced glycemic load and smaller ice crystal sizes. As a result, to obtain a high-quality diet product with improved rheological, thermal, and microstructural properties, GFF should be added at a rate of 1 to 2% [27].

Regardless of the potential benefits of amaranth and flaxseed, there is little information on their combined effect on the physicochemical and functional properties of extruded products. Extrusion of six mixtures in a twin extruder was done with different proportions of amaranth (18.7–33.1%), flaxseed (6.6–9.3%), maize grits (55.6–67.3%), and minor ingredients (4.7%) for the production of extrudates. According to the study, the amount of amaranth and flaxseed used in the development of extruded products had major effects on their functional

and physicochemical properties. Extrudates with higher proportions of amaranth and flaxseed had higher insoluble and soluble fiber content. The highest flaxseed proportion had the highest soluble fiber content (1.9 percent). The protein content of the extruded products was high (>12%), which was significantly high than that of commercial breakfast cereals. Aside from these attributes, the extruded products obtained had a healthy caloric density (<5%). Extruded products containing low amounts of starch and high levels of fiber produced extrudates with a low expansion index and more hardness. As a result, extruded products containing amaranth (18.7–22.9 percent), flaxseed (8.6–9.3 percent), and maize grits (63.8–67.3 percent) had acceptable physicochemical and functional properties [28].

Flaxseed is a vital oil crop. By-products of flaxseed oil extraction have a high nutritional value. Therefore, the effectiveness of flaxseed industry by-products (flour (FF) and marc (FM)) as functional raw materials in bread production was highlighted in one study. Flaxseed by-products were added to wheat bread in amounts of 5, 10, and 15%. The effect of adding FF and FM to bread on its quality, chemical composition, and consumer acceptance was studied. According to the outcome of the research, adding FF and FM increased bread yield by 146.6 and 148.4 percent, respectively, for samples with 15% FF and FM addition, compared to the control bread (13.5%). According to texture analysis, Both by-products changed the average values of hardness, chewiness, and firmness, as well as the color of the crumb. Flaxseed by-products improved crumb water content but showed a negative impact on specific volume and pore size distribution, whereas FM has a lesser impact. The introduction of 5% flax components increased the bread's nutritional value while lowering its calorie content thus being beneficial for diabetics. According to the findings, adding 10% flaxseed marc to bread results in bread with high nutritional quality and satisfactory sensory attributes [29].

Diabetes management relies heavily on nutrition, and foods with a low glycemic index are becoming increasingly popular because they slow the release of glucose into the bloodstream. It's critical to create a low-glycemic food mix using locally available ingredients for daily diets. Therefore, an investigation of the glycemic index of traditional recipes (dosa, mudde, and roti) made from developed millet-based food mix, as well as their impact on pre-diabetic subjects was conducted in research. Finger millet, little millet, defatted soy flour, whole green gram, fenugreek seeds, flax seeds, curry leaves, bitter gourd, and skimmed milk powder were used to make a millet-based food mix. Protein (19.41 g/100 g) and dietary fiber (21.11 g/100 g) both were present in the developed millet-based food mix. With a glycemic load of 11.05, 18.43, and 18.09, the glycemic index of dosa, mudde, and roti was found to be 37, 48, and 53, respectively. All three developed products, however, had a lower glycemic index (<55), as well as a reasonable glycemic load of (<20). Moreover, dietary supplementation on pre-diabetic subjects revealed a significant decrease in FBS (120.50 ± 18.73 to 97.81 ± 20.00) and HbA1c (6.14 ± 0.30 to 5.67 ± 0.40), indicating that they were a wiser choice for diabetes management [30].

The previous studies discovered the impact of diet and various nutrients on metabolism, including the use of low-carb food in the treatment of cardiovascular disease, diabetes, and metabolic syndrome. In this frame of reference, an optimal combination of ingredients for the development of bread, which could be used to improve the course of these diseases, as well as to be consumed by groups of individuals with gluten, milk, and sugar intolerances was studied. Two bread formulations containing flaxseed flour, eggs, vegetable oil, baking soda, salt, and natural apple cider vinegar were formulated and evaluated during the project. The liquid component was represented by oat milk in the first sample and hazelnut drink in the second. The resulting bread was compared to commercially available analogs. The quality analysis revealed that the resultant bread met the quality standards.

Both samples had lower calorie (18%), carbohydrate (37.5%), and higher protein content (13.5%). It was discovered that adjusting the nutritional value allowed the product to be integrated into a low-carb diet, which was particularly essential for people with diabetes and metabolic syndrome [31].

Flaxseed has been found to help lower and stabilize blood glucose levels in various investigations. While one study was conducted to investigate whether flaxseed could reduce blood glucose response more successfully when consumed as a single 30 g portion or as a split portion thrice a day. It was a cross-over study with a randomized, repeated measures design. 15 healthy members were provided one of three options: (1) 3 flaxseed muffins containing a total of 30 g flaxseed consumed once in the early hours, (2) 3 flaxseed muffins consumed at 3 distinct time intervals throughout the day (10 g flaxseed per muffin), or (3) 3 control muffins consumed at 3 distinct time intervals throughout the day (0 g flaxseed per muffin). A continuous glucose monitor was used to assess the 24-hour blood glucose reaction. Muffins made were high in crude protein, fatty acids, energy, and fiber profile while low in carbohydrates. The findings showed that flaxseed muffins given thrice a day were more effective than control muffins at reducing and sustaining blood glucose levels over 24 hours. It was observed that Flaxseeds should be consumed in small amounts throughout the day, not all at once [32].

Analysis of the impact of varying sugar, fat, and prebiotic fiber levels in powder preparations used to make mangaba ice cream was studied in one research. P1, P2, and P3 were the first three simple powder mixes for ice creams, and they were also known as powder preparation. Cream milk powder, light milk powder, flaxseed meal powder, corn syrup powder, inulin, FOS, and stabilizers (at different concentrations) were among the ingredients that were required for the production of ice cream. The powdered preparations were tested for solubility, hygroscopicity, water content, and microscopic characteristics. The physicochemical properties, quality attributes, overrun, nutrient profile, mineral absorption simulation in vitro, rheological characteristics, fructooligosaccharide quantitative analysis, and sensory acceptability of the ice cream produced by these mixtures were all examined. As it was discovered that the ice cream mangaba is a source of vitamin C (17–25 mg.100 g-1), dietary fiber (4.9–8.6 g.100 g-1), and prebiotic (FOS content: 3.06–5.68 g.100 g-1), calcium (3.38–3.64 g/kg-1), and contains low sodium (0.48–0.60 g/kg-1) the study concluded that the incorporation of prebiotic fibers and the reduction of sugar and fat levels can provide nutritional benefits. Inulin and FOS, on the other hand, were likely accountable for the increase in solubility (64.22 percent, 71.67 percent, and 79.73 percent) and reduction in hygroscopicity (6.06, 4.23, and 3.14 g/100 g) of powdered ice cream preparations. It was concluded based on findings that incorporating ingredients such as mangaba pulp, flaxseed, prebiotic fibers (inulin and FOS), and lowering sugar and fat levels can strengthen the technological and nutritional characteristics of ice cream [33].

Oropharyngeal dysphagia is a serious type of dysphagia, which refers to difficulty swallowing – moving food from the mouth to the stomach, requires more effort than usual. This mechanical disorder has been linked to aging, neurological issues, brain and neck cancer, cerebral palsy, Parkinson's disease, and benign esophageal stricture, among other things. Oropharyngeal dysphagia patients are given a viscosity-modified diet with thickeners to avoid swallowing problems. Although most commercial products contain xanthan and starch, flaxseed gum (FG) is a potential thickener for liquid foods that also has health benefits. Concerning the use of flaxseed gum (FG) in thickening methodologies for dysphagia patients, one investigation was done to check the relationship between the rheological properties of thickeners and their advantages in terms of nutrition such as enhancing fibers, and phenolic content while reducing glucose absorption. FG was combined with

modified starch (MS) and Xanthan gum (XG), with the concentrations of the biopolymers varied according to a central composite rotational design, with the evaluated responses being rheological and color properties in water. Furthermore, the amount of glucose released following in vitro digestion was assessed and compared to a commercial MS-based thickener. It was observed that the shear time-independent and shear-thinning behavior of all formulations was primarily influenced by the concentrations of XG and MS. The formulations exhibited a predominant elastic character in oscillatory measurements, which was attributed to MS and primarily to XG, which, despite its lower concentration, imposed a similar influence on this rheological property. The most significant factor influencing viscosity, however, was the increase in FG concentration. Surprisingly, the commercial formulation had a significantly higher glucose release than the suggested FG/MS/XG-based formulations. Hence, FG-based thickened beverages could have an advantage over those based on MS in this due consideration, enhancing the quality of life of dysphagia patients and lowering the amount of glucose released in vitro after digestion [34].

2.2 Patent based information

Patented inventions that include the food formulation containing flaxseeds have been included in this category, and it was also investigated whether these foods can be included in the diabetic patient's diet in the information.

Over the last century, human dietary habits have changed dramatically due to the advancement of civilization & industrialization. The dietary intake of linoleic acid, an essential fatty acid of the omega 6 fatty acid group, increased as the production and consumption of oil seeds and oil rose. This resulted in a shift in the omega 6:3 fatty acid ratio in human diets from around 1:1 to 10–40:1. This shift plays a critical role in the treatment of so-called "lifestyle diseases," such as cardiovascular disease, hypertension, type 2 diabetes, and viral infections. In this context, one research was conducted and patented under application number, US0360073A1. The primary goal of this invention was to develop an optimized nutrient fatty acid composition that can be used to resolve a dietary imbalance in essential fatty acid consumption in human beings in a simple, safe, practical, and cost-effective manner. Oil seeds with omega 6 to 3 fatty acid ratios of 1:1 to 1: 1.25 were used to make optimized nutrient fatty acid compositions, which were stabilized with vitamin E 0.8–4 mg/ml. After cleaning, drying, and dehydrating the ingredients, oil was extracted from soybeans, flaxseed, walnut, perilla seed, rice bran, sunflower seed, evening primrose seed, high GLA safflower seed, garden cress seed, sachainchi beans, and green algae using conventional methods. After the final product formulation, 10 patients with metabolic syndrome (high blood pressure, abdominal obesity, increased fasting glucose, elevated fasting triglyceride, and low HDL) were chosen for the study. The patients were divided into two groups after their physical examination. Both groups were told to keep taking their medications and to follow a low-calorie, low-fat, low-carbohydrate diet with moderate exercise. In addition, the second group was instructed to consume 25 mL of optimized nutrient oil as cooking oil daily. When compared to the first group, the second group on optimized nutrient oil had a considerable reduction in weight, abdominal girth, blood pressure, sugar levels, CRP, SGPT, and triglyceride, as well as an increase in HDL. Furthermore, the optimized fatty acid composition could be used as food, beauty products, and a delivery vehicle for drugs and nutrients [35].

With the constant intensification of the rhythm of real-life and work, people's spirits are constantly in a state of high pressure, overload, causing a rise in blood sugar, if things continue like this, easily cause some people to develop diabetes. Which affects their standard of living. A good eating style is needed to prevent

and treat the serious problems associated with diabetes. Therefore, CN107373642A disclosed a kind of diabetic special food formula including; whey separated protein powder with a precise weight of 15,30 parts by weight of plant fat powders (including 18 parts by weight of medium-chain triglycerides) 8 parts by weight sunflower oil powders, 4 parts by weight flaxseed oil), 10 parts by weight dietary fibers, 45 parts by weight carbon water compound, 2 parts by weight soybean phosphatide, 0.2 parts by weight phytosterol, 0.3 part by weight of vitamin, 0.3 parts by weight mineral matter. Following the formulation of the food product, a functional test on 30 diabetic patients was performed. Patients were told to keep taking foodstuff on daily basis. Evaluation at the end of the test discovered that the diabetic patient's symptoms had significantly improved[36].

In another patent CN106266429A, formulation of preparation of a kind of diet therapy soup including; Radix Puerariae 20–50 parts, Fructus Lycii 10–30 parts, Flaxseeds 5–30 parts, Rhizoma Dioscoreae 10–30 parts, leaf of Moringa 5–20 parts was Described. It was a powdered formulation that could reconstitute in boiling water, all ingredients of diet therapy soup worked together in harmony to treat diabetes and improve the immune system of Susceptible people by lowering blood glucose levels. Each ingredient, such as Radix Puerariae, Rhizoma Dioscoreae, Fructus Lycii, and Flaxseeds, was cleaned, pulverized, and concentrated to form a thick paste, which was then pulverized and dried to form a powder. All of the powders were combined, resulting in a uniform dry soup mix. Furthermore, this composition can be used to make beverages, food, medicine, and so on, and it is relatively suitable for diabetic patients, as it has the potential to have a blood sugar lowering function [37].

Regardless of the type of diabetes, keeping blood glucose levels within a healthy range is critical. Along with seeds, cereals have an important role in the diet of a diabetic patient. Barley is a cereal grain that has traditionally been referred to as "gluten grains." Barley is high in dietary fiber, beta-glucan, molybdenum, manganese, and selenium. Barley is also high in copper, vitamin B1, chromium, phosphorus, magnesium, and niacin. However, because whole grain barley is not easily palatable, it is not widely consumed as a staple food. As a result, there is a need for a technique of processing whole-grain barley that is palatable while retaining the grain's nutrients. The technique of formulation of barley-based compositions comprising barley, other cereals, pulses, spices, dry fruits, and flavoring agents was disclosed in patent application AU100571A4. The pre-mixed barley-based composition was made up of barley in the 45–75 wt percent range; wheat in the 20–40 wt percent range; and soybean in the 5–20 wt percent range. Whole green gram, broken green gram, whole Bengal gram, broken Bengal gram, whole lentil, and broken lentil were among the pulses. Coriander, cumin, carom, flaxseed, fenugreek, red chili, turmeric, asafetida, and salt were among the spices used. The steps for preparing the pre-mixed barley-based composition included cleaning the raw materials, optionally roasting the cleaned raw materials, mixing the cleaned and optionally roasted material to obtain a mixture, grinding the mixture to obtain a fine flour or powder, and packaging the flour or powder. Resultant Pre-mixed barley-based compositions could be used to make a variety of food products (flat bread, roti, chapatti, paratha, khakra, thalipeeth, cutlet, pancake, health drink) that could be consumed by both healthy people and people suffering from obesity, dyslipidemia, diabetes, and other conditions. Another advantage of this technique was powder formulation was free from chemical preservatives [38].

Flaxseed cake is a byproduct of flaxseed de-oiling that contains lignan, flaxseed gum, and cyanogenic glycoside. After consumption, cyanogenic glycosides can decompose in vivo into hydrogen cyanide, causing poisoning in the human body and death. The presence of cyanogenic glycoside in flaxseed limits the use of

flaxseed and its byproducts in the food industry. To broaden the use of flaxseed in the food industry, The inventors revealed a type of red yeast rice Flaxseed cake fermentate and its application in the field of food processing technology in patent CN107136183A.The following steps were taken to prepare the product: The first step involved the detoxification of the Flaxseed cake, in which the water content of the Flaxseed cake was controlled at 170-200 g/kg and the detoxification was performed using a microwave power of 800 W for 8 minutes. The Flaxseed cake was fermented and detoxified further in the second step by activating the Monascus slant 3–4 times and accessing the seed culture medium. Then, after accessing the fermentation medium, concentration was done at 30 degrees Celcius for 3 days. The total incubation period was 5–7 days. As cyanogenic glycoside is unable to meet food safety requirements due to the limitations of traditional Flaxseed cake detoxification mode, so, flaxseed cake is never used as raw food material, but the main advantage of this invention was that it used microwave detoxification and secondary microbial fermentation to remove the mode of poison so that cyanogenic glycoside reaches below 0.015 mg/kg. Another advantage was that the entire process was inexpensive. In the functional test, Red yeast rice Flaxseed cake fermentate was used to make biscuits. 2 L Flax seed oil was used in the preparation of the biscuits. Wheat flour, egg, white granulated sugar, edible salt, ammonium hydrogen carbonate, sodium bicarbonate, and water were also used. The made biscuits were found to be free of cyanogenic glycosides. In addition, Both red yeast rice and flaxseeds can help with hypotension, blood glucose control, and cholesterol reduction. Flaxseeds have antitumor, anti-aging, and anti-renal failure properties. Therefore, Red yeast rice Flaxseed cake fermentate was beneficial to diabetic patients, aged women who lack nutrition, and people suffering from obesity [39].

We all know about the benefits of flaxseed, but such ingredients should be used in conjunction with flaxseed, which can make a significant contribution to the treatment of diabetes, so such food cannot be considered anything less than a boon. Edible seaweed is high in sugar, terpene, alkaloid, and polyphenols; these active materials have a variety of benefits including hypoglycemic, decompression, antibacterial, and anti-oxidant properties. Kelp is a rich source of dietary fiber, nutrients like vegetable protein, and has a high nutritive value, is extremely beneficial for the auxiliary treatment of diabetes. In this context, patent CN108522970A disclosed a full nutrition formula food made of a type of seaweed raw material for diabetic patients. Kelp powder, Buckwheat, soybean powder, Peanut powder, Walnut powder, Flaxseed meal, Kudzu-vine root powder, and Tomato powder were used in a 3:15:8:4:1:1:8:2 ratio, along with a small amount of nutrition fortifier. Preparation methods included polishing, mixing, homogeneous, and freeze-drying. The formula food produced could effectively control blood glucose and replace staple food to provide sufficient daily nutrition demand for diabetes patients and also cost was relatively low. Furthermore, because it is made entirely of natural food ingredients, it retains a wide range of natural sugar-reducing substances [40].

The process for preparing a mixture by mixing two types of ingredients was disclosed in Patent KR101850955B1. The type 1 ingredient was 54.5–71.5 percent by weight of flax, 8.0–11.5 percent by weight of acid, 4.5–7.4 percent by weight of onion, 1.5–2.5 percent by weight of pine needle, 1.5–2.5 percent by weight of Angelica keiskei, 1.5–2.5 percent by weight of blackberry, and type 2 ingredient was 50–54% by weight of the upper leaves and 46–50% by weight of the oak. The leaves were extracted for 2 to 3 hours at a temperature of 70 to 80 °C using hot water. The extract was then filtered to obtain filtrate, which was concentrated until it reached 23 Brix or higher, after which the mixture of type 1 ingredients and extract concentrate of type 2 ingredients was mixed in a ratio of 1: 0.4–0.6. The final food produced could be used to prevent or treat diabetes [41].

Omega-3 fatty acids can be found in a variety of foods, including fish and flaxseed, as well as dietary supplements like fish oil. Alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) are the three main omega-3 fatty acids. Plant oils such as flaxseed, soybean, and canola oils are high in ALA. Fish and other seafood contain DHA and EPA. Omega-3 fatty acid-rich diets may help diabetics lower their insulin resistance. Omega-3 fatty acid-rich diets may lower the risk of heart attacks, strokes, macular degeneration, and certain cancers. Many types of research have been conducted to create omega-rich foods. A type of −3 sour milk powder preparation was discovered in one of these studies, and it was patented under the number CN104542974B. It was made up of 15–25 parts of flaxseed oil microcapsule powder, 70–83 parts of milk powder, and 25% parts of probiotic powder in weight proportions. Each component material was mixed in equal increments, and the resulting powder was packed in a vacuum nitrogen filling packing machine with a sterile aluminum foil bag. Omega-3 supplemented sour milk powder could be stored at room temperature and had a long shelf life. It had numerous health benefits; it was easily soluble in water, could be dispersed into yogurt liquid, and could be reconstituted with 30–37 °C warm water to make instant drinks. It was found to be beneficial in the improvement of intestinal canal function, nutrient absorption, immunity, brain cell, intelligence, and optic nerve systematic growth, memory, and could prevent and improve chronic diseases like cardiovascular and cerebrovascular disease, cancer, and diabetes [42]. Another study, Patented in 2018 under application number CN108685006A disclosed the preparation of omega-3 solid beverage comprised of 60–96 parts by weight of linseed oil microcapsule powder, 0.02–0.1 parts by weight of probiotics, 3–10 parts by weight of compound fruit, and vegetable ferment, 3–20 parts by weight of bamboo-leaves flavones, 1–10 parts by weight of inulin. *Bifidobacteriumlongum*, *Lactobacillus paracasei*, and *Lactobacillus rhamnosus* were used as probiotics in the invention. Pawpaw, pineapple, berries, blackcurrant, melon, walnut, 10 parts black fungus, banana, grape, apple, lemon, longan, mango, radish, mushroom, cucumber, pumpkin, wild rice stem, tomato, and green cucumber were the main vegetables and fruits used in the vegetable and fruit ferment. Probiotics and linseed oil microcapsule powder were first pressed and uniformly mixed, then compound fruit and vegetable ferment was added and uniformly mixed, after that bamboo-leaves flavone were added and uniformly mixed, and finally plus inulin was uniformly mixed using the equal increments method. The resulting solid beverage was found to be effective in preventing and treating diabetes, as well as slowing diseases like kidney disease, cancer, and gastrointestinal function weakness, as well as promoting nutrient absorption [43].

US0335796A1 described the preparation of a low-calorie optimized nutrient food that contained all of the essential and non-essential nutrients in the proper proportions for optimization of body systems and, as a result, maintaining health, preventing diseases such as hypertension, heart diseases, cancer and diabetes, and delaying aging, with a calorie count of about 650. More specifically, the optimized nutrient food contained a 1:1 ratio of omega 3 to omega 6 fatty acids; high dietary fiber content; high protein with complete amino acids; and vitamins and minerals optimized according to FDA daily value recommendations, capable of providing about 650 calories per 150 g, but free of cholesterol, trans fat, preservatives, and artificial flavorants and colorants. Protein source was obtained from soya beans, goa beans, watermelon seeds, flaxseed, perilla seed, hemp seed, sachainchi seed, sunflower seed, safflower seed, almond, garden cress seed, oats, gingili seed, fenugreek, pumpkin seeds, pistachio, corn seed, rapeseed, poppy seed, sesame seed, black gram, Bengal gram, and green gram. Flaxseed, perilla seed, garden cress seed, mustard seed, canola seed, chia seed, sachainchi, hemp seed, walnut, clary sage seed were chosen as omega

3 sources, and gingili seed, sunflower seed, safflower seed, watermelon seed, corn seed, almond, cashew nut, groundnut, pumpkin seed, hemp seed, black currant seed, poppy seed, rapeseed, borage seed, were chosen as omega 6 sources. Oats bran, rice bran, fenugreek seed, soya beans, flaxseed, garden cress seed, rice bran, chicory root, aniseed, sun root, perilla seed, and safflower seed were chosen as dietary fiber sources. The functional test included 30 patients between the ages of 25 and 40 who were diabetics with fertility issues who were planning a pregnancy. Two groups of patients were created. Metformin 500 mg twice daily was given to all patients, along with dietary advice. Other standard modern medical treatment for their fertility issues was also given to them. All of the patients in the first group were instructed to cut back on fat, starch, and sugar in their diets, as well as engage in light to moderate exercise. The second group was told to eat 100 grams of optimized nutrient food every day for 2 months, along with low-calorie vegetables and fruits, and to avoid eating anything else. It was observed that both groups improved their blood sugar levels for 30 days, but the second group, which followed an optimized nutrient food diet, had significantly better blood sugar control. Both groups had improved blood sugar and HbA1C levels at the end of the 60 days. However, 80% of the first group had not achieved adequate blood sugar control before conception, necessitating the use of insulin. Due to exhaustion, the patients in the first group were unable to restrict their carbohydrate intake. Those on a nutrient-dense food diet, on the other hand, saw significant improvements in blood sugar and HbA1C. With an optimized nutrient food diet, even overweight and obese diabetic patients improved significantly, and none of them required insulin before conception. As a result, Optimized nutrient food having about 650 calorie optimal nutrition was the simple, safe, and economic answer to the prevention of lifestyle-related diseases [44].

CN110384123A disclosed the preparation method of Low-sugar high-fat mooncakes. Ketobodies are produced by a high-fat diet, which regulates glucose metabolism, reduce carbohydrate intake, block the energy source of tumor cells, reduce intracellular active oxygen ROS (reactive oxygen species), and thus including high-fat diet on daily basis can protect the human body against diabetes, Alzheimer's disease, and Parkinson's disease. In the invention, Mooncake wrapper 33 g and fillings 17 g were used to make a low-sugar, high-fat mooncake, with a fat: protein+sugar mass ratio of 1.0–10: 1–0.1. The moon cake wrapper was made of the following materials in the following mass percents: fatty microcapsule powder 26–48 percent, resistant starch 21–35 percent, sugar alcohol 4–7%, resistant dextrin 9–20 percent, polydextrose 3–6%, phosphatidase 2–6%, dried hen egg yolk 2–10%, egg liquid 11–18 percent. The material used for fillings were taken in the following mass percents: fat meat 11–22 percent, veterinary antibiotics or nut powder 19–33 percent, yolk 30–47 percent, calcium caseinate 2–6%, grease 1–5%, sugar alcohol 0.5–3%, resistant starch 3–11 percent. Antierythrite, D-sorbate, maltitol, xylitol, isomalt, lactitol, and one or more mannitol were among the sugar alcohols used. In the filling for grease, coconut oil, palm kernel oil, medium-chain triglyceride, peanut oil, rapeseed oil, olive oil, tea oil, high oleic sunflower oil, rice oil, pine-seed oil, soybean oil, corn oil, flaxseed oil, cottonseed oil, sesame oil, walnut oil, perilla herb oil, docosahexaenoic acid DHA algal oil, arachidonic acid ARA oil, fish oil, pig One or more of oil, chicken fat, and sheep oil were used. Ovum Anas Domestica yolk, egg yolk, goose egg yolk, turkey yolk, pigeon yolk, ostrich yolk, quail One or more of quail egg and emu egg were among the fillings' yolks. Filling vegetables included pumpkin, wax gourd, purple sweet potato, sweet potato, taro, Chinese chestnut, carrot, potato, water chestnut, corn, cassava, and lotus rhizome dry product; fruit included pawpaw, apple, pear, coconut, orange, lemon, strawberry, blueberry, and blackberry dry product; and nut powder included pine nut, walnut, and peanut powder. Furthermore, technical issues were resolved to make it low in sugar but still palatable [45].

US10765318B2 disclosed a regimen that included a meal plan, exercise, and specific supplements for cleansing, overcoming bodily deficiencies, and reversing Type II diabetes. In the invention, nutritional supplement preparation was described. Vitamins A, C, D, E, K, K2, B1, B2, B3, B6, B9, B12, B7, B5, Minerals Calcium, Iron, Magnesium, Zinc, Selenium, Copper, Manganese, Chromium, Molybdenum, Potassium, and stabilized fatty acid blend consisting of Borage Oil, Flax Seed Oil, and Algae Oil was included in the recommended supplement. Aside from that, the supplement contained an organic vegetable and fruit blend that included Garlic, Jerusalem Artichoke, Cinnamon Verum, Raspberry Ketones, Rhodiola Crenulated and Glucomannanase, Turmeric, CoQ10 Ubiquinol, Black Strap Molasses, Kelp, and Probiotics like Lactobacillus, Acidophilus, L-Plantarum, Bulgaricus, Streptococcus, Thermophilus and *Enterococcus Faecium*. Furthermore, the meal plan and mild to moderate exercise were also advised in the disclosure. A case study was carried out on 20 patients who had Type 2 Diabetes and were taking diabetic medication. The study's patients all have A1c levels ranging from 6.0 to 12.5. All patients were advised to take supplements in addition to a healthy diet and exercise. It was discovered that everyone who used the invention reduced or eliminated their diabetic medications, lost weight, or had personally expressed having more energy [46].

CN111466425A revealed a method of making a low-carbohydrate flaxseed nut wafer. The wafer was made up of the following raw materials in weight order: 40–80 parts flaxseed, 5–30 parts nut grains, 0–0.06 part sweetening agent, 0–0.5 part psyllium husk powder, 15–30 parts sugar substitute powder, 2–6 parts thickening powder, 3–5 parts edible oil, 1–5 parts tackifying powder, 0–1 part yeast extract and 80–100 parts of water. Material preparation, dissolution, whipping, soaking, quantitative squeezing, trowelling and forming, and baking were all used to make the wafer. The low-carbohydrate nutritional wafer was high in protein and dietary fiber, and it was also high in Omega-3 and other minerals. It had a thin, sweet, delicious, and crispy mouthfeel and was suitable for people of all ages. It could be used as a fat-reducing meal replacement for obese people, diabetes patients, polycystic ovary syndrome patients, hyperlipidemia, and hypertension patients, and it could also be used as a leisure breakfast or nutritional meal for constipation sufferers [47].

In WO2020081417A1, a dietary supplement formulation for the treatment or prevention of digestive and immune-related disorders was disclosed. The dietary supplement could be compounded in a solid form (such as bars, wafers, or pills), a paste form, a granular form, a powder form, or a liquid form, and it could be taken orally. The ingredients of the dietary supplement include L-glutamine, mucogenic amino acid, both produced by vegan bacterial fermentation of sugar beets; lecithin derived from soy oil, oat oil, sunflower oil, safflower oil, com oil; fructooligosaccharides derived from yacon root, chicory root, Jerusalem artichoke, blue agave; beta-glucan derived from oats, barley, mushrooms, seaweed, algae, yeast cell wall; A oligosaccharide derived from the bran tissues of wheat, oats, barley, rice, millet, psyllium, flax, rye; RS-4 starch derived from oats, yacon root, chicory root, flax, acacia, com. Emulsifiers and nutricine, (that bind to and eliminates pathogenic bacteria in the digestive tract), were also included in the formulation. The dietary supplement was said to reduce systemic inflammation, which is the cause of most chronic diseases like diabetes, cardiovascular disease, and cancers, by increasing the impermeability of the gut lining and balancing the bacteria components of the microbiota [48].

An enteral or oral nutritional composition comprised of whole food components, herbs or spices blend, fat, carbohydrates, protein source, fiber source, and micronutrients was described in WO2020039277A1. Cereals, fruits, and vegetables were included in the whole food supplement. Fruits included banana, apple, guava, orange, grapes, mango, pomegranate, and chickoo; vegetables included

beetroot, tomato, carrot, radish, onion, and spinach; and cereals included wheat, rice, soybean, and chickpea were utilized in the supplement. For fatty acids supplementation α-linolenic acid, docosahexaenoic acid, eicosapentaenoic acid, flaxseed, walnuts, almonds, algae, krill, were used. All of the ingredients were cooked for 10–30 minutes at 60–80 degrees Celsius, then blended and homogenized into a powder that could be reconstituted with water or juice. It was noticed that the invention of enteral/oral nutritional composition satisfied the specific nutritional needs of patients with various illnesses, such as cancer, diabetes, kidney, and liver diseases, as well as patients who had undergone surgery [49].

In KR20210012287A, meat powder and antidiabetic ingredients were mixed with whole wheat flour, rye flour, and wheat flour used to make noodles for diabetic patients. Based on a total of 100 parts by weight of nutritional noodles, the meat powder was 5 to 30 parts by weight and the antidiabetic material powder was 5 to 30 parts by weight. Broccoli, onion, eggplant, garlic, arbor, deodeok, burdock, purple pork potato, bitter gourd, flaxseed, nuts, brown rice, and barley were among the anti-diabetic ingredients. The noodles were cooked at a low temperature, which has the advantage of reducing nutrient loss by minimizing nutrient destruction. The meat powder was made using beef, pork, chicken, lamb, and duck. The resulting noodles were low in calories, high in protein, high in vitamins and minerals, and low in cholesterol, making them an ideal diabetic food [50].

3. Statistics of publications

The purpose of this review is to cover the most relevant papers and patent applications that attempt to provide a clear picture of flaxseeds used in various food products and how these food products can benefit diabetics. This review included 34 kinds of research, 18 of which were paper publications and 16 of which were patent applications. These studies are classified into five major categories based on the end product. **Figure 4** depicted the percentage breakdown of the various categories covered in the review. Out of the 34 reviewed studies, 12 were bakery products, so this category took first place with 35.29 percent and contributed the most to the literature review. The remaining 64.71 percent was distributed as follows: 26.47 percent of extruded snacks and beverages secured second place with 9 researchers, 17.64 percent of nutritional supplements secured third place with 6, With 4, 11.76 percent of dairy products secured fourth place, and 8.82 percent of food mixes secured fifth place with 3 studies. Out of 16 applications, six have been taken by

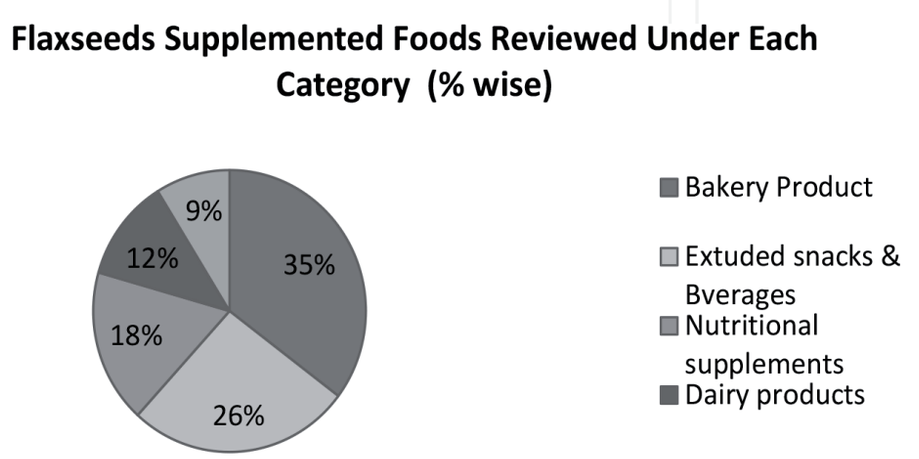

Figure 4.
Types (in percentage) of food reviewed under each category.

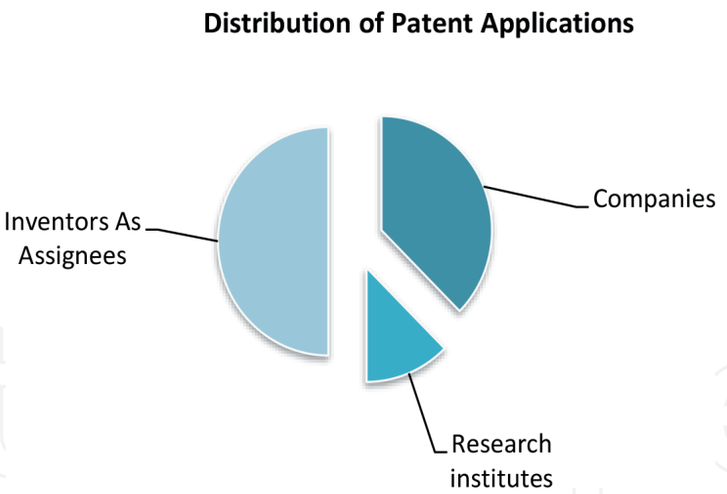

Figure 5.
Distributions of patent applications.

companies and two have been taken by research institutes, and the remaining eight applications are still not commercially available. Seven different inventors enjoy 50% of the total share with 8 patent applications out of a total of 16 patents covered in this review. One inventor, V.M Jolly captured 2 patents. These patents are not still claimed by any company, lab, or institute therefore not commercially available. Six different patents were captured by 4 different companies that enjoy 37.5% of the total share. Hangzhou Tianlong health products Co. Ltd. captured 3 patents and enjoys an 18.75% share of 37.5%. Shenzhen Jielikang biological Tech. Co. Ltd., Hockings consulting Inc., Guangzhou Saliai stemcell Science and Tech. Co. Ltd., each availed 6.25% of 37.5% with 3 patents. Two other research institutes Shanxi biological institutes and Zhejiang Ocean University captured a collective share of 12.5% as they claimed 1 patent each. **Figure 5** represented the distribution of different patent applications claimed by companies, institutes & inventors as assignees.

4. Challenge faced by flaxseeds

Humans across the region are adopting healthier lifestyles, which is one of the major factors driving demand for flaxseeds, which is linked to a variety of health benefits. Even so, the flaxseeds must face some obstacles that cannot be overlooked. Chia seeds are one of the flaxseed substitutes in the market. These are a close substitute for flaxseeds due to their nutrient content and health benefits. Both flax and chia seeds are high in nutrients and have been linked to health benefits such as lower blood sugar, a healthier heart, and cancer prevention. When compared to flaxseeds, chia seeds aid in the reduction of food cravings while also being high in fiber [51]. In this context, a study was conducted in which three separate occasions, 15 healthy participants (5 Males and 10 Females having age between 23 to 27 years; BMI: 22.2 ± 0.8 kg/m2) were randomized to receive a 50 g glucose challenge alone or with either 25 g ground Salba-chia or 31.5 g flax. At fasting and 2-hours postprandially, blood glucose samples and satiety scores were collected and investigated. According to findings in comparison to glucose control, Salba-chia reduced blood glucose area under the curve more (82.5 ± 19.7 $mmol^{-1}$ P0.001) than flax which reduced the area by 60.0 ± 19.7 $mmol^{-1}$ (P = 0.014), over 120 minutes. When compared to flaxseeds, Salba-chia significantly reduced mean ratings of the urge to eat, prospective consumption, and total appetite score [52]. They also have a competitive advantage over flaxseeds in that they do not go rancid and do not require grinding due to their smaller size [53]. As a result, high competition from chia seeds has created a difficult situation for flaxseed.

5. Future directions

The oil and fibrous plant flax (*Linum Usitatissimum* L.) has been used by for over 600 decades and it was one of the first plants to be domesticated. However, because of its high nutritional value, flaxseed is becoming more popular in the nutraceutical segment as people become more aware of its health benefits and applications in the food industry. There are some aspects of this field that have yet to be explored. An attempt has been made in this article to shed some light on those points as well.

- People today are well aware of the significant relationship between diet and health. They believe in letting the food, rather than medicine, be your medicine. Therefore, as the demand for functional foods grows, so does the amount of waste produced by them. If this waste is not properly disposed of, it can harm the environment, as well as the nutrition and economy. As a result, this aspect must also be considered. However, the presence of anti-nutritional compounds, particularly cyanogenic glycosides, which are an essential component of flax, present in the flaxseed meal left after oil extraction has limited its applications in food and feed. Many techniques for reducing cyanogenic compounds in flaxseed meals on a lab scale, such as boiling in water, microwave roasting, wet autoclaving, acid treatment, and extrusion cooking, can be used to successfully reduce or eliminate anti-nutritional components in flaxseed meal [54]. However, these methods have a significant impact on beneficial polar compounds like lignans. Cold-pressed flaxseed meal can be a good choice for removing the cyanide while retaining the beneficial nutrients, protein, fat, fiber, and lignans at the same level as untreated flaxseed meal. One research was conducted using the cold pressing method of the by-product left over after extracting oil from flaxseed as a fat-replacer in low-fat salad dressing formulation, which is an excellent waste-to-wealth strategy [55].

- Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are not produced by the human; they must be consumed or formed through metabolic processes of ω-3 fatty acids, such as linolenic acid. Current eating habits have resulted in a significant reduction in daily ω-3 fatty acid intake, which is now below the recommended levels, necessitating the need to supplement food with ω-3 fatty acids. One of the current strategies for staying healthy is to incorporate Omega-3 fatty acids into new products in the medical and health food fields. However, there is a problem with ALA, it is strongly heat-sensitive, reactive towards oxygen, and metal ions, and during processing and storage, it produces rancid flavors compounds. Flaxseed oil's nature restricts its use in the food and dairy industries. Several authors have recently worked on flaxseed oil stabilization using various technologies such as ultrasonication and microencapsulation, as well as developing emulsion and microcapsules. One significant disadvantage is that the encapsulation process could cost more than twice as much as the ω-3 ingredient. Furthermore, due to storage, the ALA content is also easily reduced [53, 56]. As a result, more work is needed to improve its stability and quantification after it has been fortified in food products.

6. Conclusion

The goal of this study was to summarize the use of flaxseed to enrich a variety of products, including baked, dairy, extruded, and snack foods, as well as their impact on diabetic patients. Flaxseed can help encourage the development of healthy

alternatives by strengthening the nutritive value of foods by lowering salt, sugar, and saturated fat content while improving the content of omega-3 fatty acids and other bioactive components that may help diabetic patients manage their condition. More research is required to develop environmentally friendly and budget-friendly technologies for extracting bioactive from flaxseed by-products. Stability practices for ALA in the development of value-added flax seed enriched products will also prove to be a ray of hope for the food industry.

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References

[1] K. K. Singh, D. Mridula, J. Rehal, and P. Barnwal, "Flaxseed: A potential source of food, feed and fiber," *Crit. Rev. Food Sci. Nutr.*, vol. 51, no. 3, pp. 210-222, 2011, doi: 10.1080/10408390903537241.

[2] O. N. Tolkachev and J. Zhuchenko, "Biologically active substances of flax: Medicinal and nutritional properties: (A review)," *Pharm. Chem. J.*, vol. 34, no. 7, pp. 360-367, 2004, doi: 10.1023/A:1005217407453.

[3] A. E. D. A. Bekhit *et al.*, "Flaxseed: Composition, detoxification, utilization, and opportunities," *Biocatal. Agric. Biotechnol.*, vol. 13, no. November 2017, pp. 129-152, 2018, doi: 10.1016/j.bcab.2017.11.017.

[4] A. Goyal, V. Sharma, N. Upadhyay, S. Gill, and M. Sihag, "Flax and flaxseed oil: an ancient medicine & modern functional food," *J. Food Sci. Technol.*, vol. 51, no. 9, pp. 1633-1653, 2014, doi: 10.1007/s13197-013-1247-9.

[5] F. Rashid, Z. Ahmed, S. Hussain, J. Y. Huang, and A. Ahmad, "*Linum usitatissimum* L. seeds: Flax gum extraction, physicochemical and functional characterization," *Carbohydr. Polym.*, vol. 215, no. June 2018, pp. 29-38, 2019, doi: 10.1016/j.carbpol.2019.03.054.

[6] P. Kaur, R. Waghmare, V. Kumar, P. Rasane, S. Kaur, and Y. Gat, "Recent advances in utilization of flaxseed as potential source for value addition," *OCL - Oilseeds fats, Crop. Lipids*, vol. 25, no. 3, 2018, doi: 10.1051/ocl/2018018.

[7] P. Kajla, A. Sharma, and D. R. Sood, "Flaxseed—a potential functional food source," *J. Food Sci. Technol.*, vol. 52, no. 4, pp. 1857-1871, 2015, doi: 10.1007/s13197-014-1293-y.

[8] R. Bernacchia, R. Preti, and G. Vinci, "Chemical Composition and Health Benefits of Flaxseed," *Austin J. Nutr. Food Sci.*, vol. 2, no. 8, pp. 1-9, 2014.

[9] C. Soukoulis, C. Gaiani, and L. Hoffmann, "Plant seed mucilage as emerging biopolymer in food industry applications," *Curr. Opin. Food Sci.*, vol. 22, pp. 28-42, 2018, doi: 10.1016/j.cofs.2018.01.004.

[10] P. Z. Zimmet, D. J. Magliano, W. H. Herman, and J. E. Shaw, "Diabetes: A 21st century challenge," *Lancet Diabetes Endocrinol.*, vol. 2, no. 1, pp. 56-64, 2014, doi: 10.1016/S2213-8587(13)70112-8.

[11] J. Beckman, *Global E&P*, IDF Diabetes Atlas, sixth edition, 2016.

[12] M. D. Nathan, "Long-Term Complications Of Diabetes Mellitus," *N. Engl. J. Med.*, vol. 328, no. 23, pp. 1676-1685, 1993.

[13] A. Alkhatib *et al.*, "Functional foods and lifestyle approaches for diabetes prevention and management," *Nutrients*, vol. 9, no. 12, pp. 1-18, 2017, doi: 10.3390/nu9121310.

[14] I. Rudkowska, "Functional foods for health: Focus on diabetes," *Maturitas*, vol. 62, no. 3, pp. 263-269, 2009, doi: 10.1016/j.maturitas.2009.01.011.

[15] P. Mirmiran, "Functional foods-based diet as a novel dietary approach for management of type 2 diabetes and its complications: A review," *World J. Diabetes*, vol. 5, no. 3, p. 267, 2014, doi: 10.4239/wjd.v5.i3.267.

[16] U. V. Mani, I. Mani, M. Biswas, and S. N. Kumar, "An open-label study on the effect of flax seed powder (*Linum usitatissimum*) supplementation in the management of diabetes mellitus," *J. Diet. Suppl.*, vol. 8, no. 3, pp. 257-265, 2011, doi: 10.3109/19390211.2011.593615.

[17] Ł. Sęczyk, M. Świeca, D. Dziki, A. Anders, and U. Gawlik-Dziki, "Antioxidant, nutritional and functional characteristics of wheat bread enriched

with ground flaxseed hulls," *Food Chem.*, vol. 214, pp. 32-38, 2017, doi: 10.1016/j.foodchem.2016.07.068.

[18] B. A. Kay *et al.*, "Pudding products enriched with yellow mustard mucilage, fenugreek gum or flaxseed mucilage and matched for simulated intestinal viscosity significantly reduce postprandial peak glucose and insulin in adults at risk for type 2 diabetes," *J. Funct. Foods*, vol. 37, pp. 603-611, 2017, doi: 10.1016/j.jff.2017.08.017.

[19] M. A. Kurek, J. Wyrwisz, S. Karp, and A. Wierzbicka, "Effect of fiber sources on fatty acids profile, glycemic index, and phenolic compound content of in vitro digested fortified wheat bread," *J. Food Sci. Technol.*, vol. 55, no. 5, pp. 1632-1640, 2018, doi: 10.1007/s13197-018-3061-x.

[20] F. Zhu and J. Li, "Physicochemical properties of steamed bread fortified with ground linseed (*Linum usitatissimum*)," *Int. J. Food Sci. Technol.*, vol. 54, no. 5, pp. 1670-1676, 2018, doi: 10.1111/ijfs.14043.

[21] F. Zhu and J. Li, "Physicochemical and sensory properties of fresh noodles fortified with ground linseed (*Linum usitatissimum*)," *Lwt*, vol. 101, pp. 847-853, 2018, doi: 10.1016/j.lwt.2018.12.003.

[22] T. Wandersleben *et al.*, "Enhancement of functional and nutritional properties of bread using a mix of natural ingredients from novel varieties of flaxseed and lupine," *LWT - Food Sci. Technol.*, vol. 91, pp. 48-54, 2018, doi: 10.1016/j.lwt.2018.01.029.

[23] N. Soltanian and M. Janghorbani, "A randomized trial of the effect of flaxseeds to manage constipation, weight, glycemia, and lipid in constipated patients with type 2 diabetes," *Nutr. Metab.*, vol 15, no. 36, 2018,doi: 10.1186/s12986-018-0273-z.

[24] N. Soltanian and M. Janghorbani, "Effect of flaxseed or psyllium vs. placebo on management of constipation, weight, glycemia, and lipids: A randomized trial in constipated patients with type 2 diabetes," *Clin. Nutr. ESPEN*, vol. 29, pp. 41-48, 2018, doi: 10.1016/j.clnesp.2018.11.002.

[25] F. Yuksel, "Investigation of certain nutritional properties of noodle enriched with raw flaxseed," *Qual. Assur. Saf. Crop. Foods*, vol. 11, no. 2, pp. 183-189, 2019, doi: 10.3920/QAS2018.1363.

[26] N. Hasaniani, M. Rahimlou, A. Ramezani Ahmadi, A. Mehdizadeh Khalifani, and M. Alizadeh, "The Effect of Flaxseed Enriched Yogurt on the Glycemic Status and Cardiovascular Risk Factors in Patients with Type 2 Diabetes Mellitus: Randomized, Open-labeled, Controlled Study," *Clin. Nutr. Res.*, vol. 8, no. 4, p. 284, 2019, doi: 10.7762/cnr.2019.8.4.284.

[27] T. M. de Oliveira Giarola, C. G. Pereira, M. E. T. Prado, L. R. de Abreu, and J. V. de Resende, "Effects of Golden Flaxseed Flour on Ice Recrystallization in Uvaia (Eugenia pyriformis Cambess.) Diet Sherbet," *Food Bioprocess Technol.*, vol. 12, no. 12, pp. 2120-2135, 2019, doi: 10.1007/s11947-019-02377-w.

[28] J. L. Tobias-Espinoza *et al.*, "Effects of the addition of flaxseed and amaranth on the physicochemical and functional properties of instant-extruded products," *Foods*, vol. 8, no. 6, pp. 1-14, 2019, doi: 10.3390/foods8060183.

[29] A. Wirkijowska, P. Zarzycki, A. Sobota, A. Nawrocka, A. Blicharz-Kania, and D. Andrejko, "The possibility of using by-products from the flaxseed industry for functional bread production," *Lwt*, vol. 118, p. 108860, 2020, doi: 10.1016/j.lwt.2019.108860.

[30] K. Geetha, G. M. Yankanchi, S. Hulamani, and N. Hiremath, "Glycemic index of millet based food mix and its effect on pre diabetic subjects," *J. Food*

Sci. Technol., vol. 57, no. 7, pp. 2732-2738, 2020, doi: 10.1007/s13197-020-04309-5.

[31] N. N. Sevostyanova, E. A. Pchelina, M. A. Vihrova, O. Y. Trezorova, and L. V. Andreeva, "Flaxseed bread for therapeutic nutrition," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 613, no. 1, 2020, doi: 10.1088/1755-1315/613/1/012137.

[32] A. Almehmadi, H. Lightowler, M. Chohan, and M. E. Clegg, "The effect of a split portion of flaxseed on 24-h blood glucose response," *Eur. J. Nutr.*, vol. 60, no. 3, pp. 1363-1373, 2021, doi: 10.1007/s00394-020-02333-x.

[33] M. L. L. Campidelli *et al.*, "Rheological, Physico-chemical and Sensorial Properties of Ice Cream Made with Powdered Form with Low Energetic Value and High Content of Prebiotic Fibers," *J. Culin. Sci. Technol.*, vol. 19, no. 4, pp. 331-351, 2021, doi: 10.1080/15428052.2020.1768995.

[34] J. M. Vieira *et al.*, "Flaxseed gum-biopolymers interactions driving rheological behavior of oropharyngeal dysphagia-oriented products," *Food Hydrocoll.*, vol. 111, no. July 2020, p. 106257, 2021, doi: 10.1016/j.foodhyd.2020.106257.

[35] V. J. Mathew, "Optimized Nutrient Fatty Acid Composition," *US0360073A*, vol. 1, 2017.

[36] H. Chen, X. Ge, F. Wang, Y. Wang, J. Cheng, X. Wang, "One kind is for diabetes B patient's diet and foodstuffs and preparation method thereof," *CN107373642A*, 2017.

[37] X. Li, X. Han, Y. Gao, "A kind of compositions being applicable to diabetes patient and diet therapy soup thereof and preparation method, "*CN106266429A*, 2017.

[38] J. Shirodkar, "Food Products and Processes for Preparation Thereof, "*AU100571A*, vol. 4, no. 12, 2017.

[39] M. Wang, P. Pan, W. Song, Z. Deng, Y. King, B. Su, Y. Cai, X. Li, X. Lu, J. Gong, "A kind of red yeast rice Flaxseed cake fermentate and its application, "*CN107136183A*, 2017.

[40] C. X. Li, H. Luo, "Diabetes full nutrition formula food and preparation method thereof made of a kind of seaweeds raw material,"*CN1085 22970A*, 2018.

[41] T. W. Kim, "Method of producing a food for preventing and improving diabetes,"*KR10-1850955B*, vol. 1, no. 19, pp. 1-17, 2018.

[42] W. Wang, "A kind of 3 sour milk powder of omega and its preparation process,"*CN104542974B*, 2018.

[43] Y. Chen, "A kind of 3 solid beverage of omega,"*CN108685006A*, 2018.

[44] V. J. Mathew, P. T. Kochery, "Optimized Nutrient Food," *US0335796A*, vol. 1, 2019.

[45] K. Fang, H. Zheng, Y. Wu, "Low-sugar mooncake high in fat and preparation method thereof," *CN110384123A*, vol. 29, no. 19, 2019.

[46] J. M. Hockings, "Mothod for treating and reversing type 2 diabetes," *US10765318B*, vol. 2, 2020.

[47] J. Lu, S. Li, X. Wu, "Low-carbohydrate flaxseed nut wafer and preparation method thereof," *CN111466425A*, vol. 31, no. 19, 2020.

[48] S. Anderson, J. Hall, M. Yoho, "Human Dietary supplement and method for treating digestive system and immune-related disorders," *WO2020081417A*, vol. 1, 2020.

[49] S. Salimath, "Enteral Or Oral Nutritional Composition," *WO20 20039277A*, vol. 1, no. 51, 2020.

[50] J. Pyo, "Preparing method of noodle for improving diabetes, and the noodle

obtained thereby," *KR20210012287A*, 2021.

[51] B. Kulczynski et al., "The chemical composition and nutritional value of chia seeds – current state of knowledge," *Nutrients*, vol. 11, no. 6, pp. 1242, 2019.

[52] V. Vuksan *et al.*, "Comparison of flax (*Linum usitatissimum*) and Salba-chia (*Salvia hispanica* L.) seeds on postprandial glycemia and satiety in healthy individuals: A randomized, controlled, crossover study," *Eur. J. Clin. Nutr.*, vol. 71, no. 2, pp. 234-238, 2017, doi: 10.1038/ejcn.2016.148.

[53] A. Gowda, V. Sharma, A. Goyal, A. K. Singh, and S. Arora, "Process optimization and oxidative stability of omega-3 ice cream fortified with flaxseed oil microcapsules," *J. Food Sci. Technol.*, vol. 55, no. 5, pp. 1705-1715, 2018, doi: 10.1007/s13197-018-3083-4.

[54] M. Imran, F. M. Anjum, M. S. Butt, M. Siddiq, and M. A. Sheikh, "Reduction of cyanogenic compounds in flaxseed (*Linum usitatissimum* L.) meal using thermal treatment," *Int. J. Food Prop.*, vol. 16, no. 8, pp. 1809-1818, 2013, doi: 10.1080/10942912.2011.608914.

[55] Z. H. Tekin and S. Karasu, "Cold-pressed flaxseed oil by-product as a new source of fat replacers in low-fat salad dressing formulation: Steady, dynamic and 3-ITT rheological properties," *J. Food Process. Preserv.*, vol. 44, no. 9, pp. 1-13, 2020, doi: 10.1111/jfpp.14650.

[56] E. Feizollahi, Z. Hadian, and Z. Honarvar, "Food Fortification with Omega-3 Fatty Acids; Micro-encapsulation as an Addition Method," *Curr. Nutr. Food Sci.*, vol. 14, no. 2, pp. 90-103, 2017, doi: 10.2174/1573401313666170728151350.